Information about GB Non-native Species Risk Assessments

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species where there is often a lack of firm scientific evidence. It also strongly promotes the use of good quality risk assessment to help underpin this approach. The GB risk analysis mechanism has been developed to help facilitate such an approach in Great Britain. It complies with the CBD and reflects standards used by other schemes such as the Intergovernmental Panel on Climate Change, European Plant Protection Organisation and European Food Safety Authority to ensure good practice.

Risk assessments, along with other information, are used to help support decision making in Great Britain. They do not in themselves determine government policy.

The Non-native Species Secretariat (NNSS) manages the risk analysis process on behalf of the GB Programme Board for Non-native Species. Risk assessments are carried out by independent experts from a range of organisations. As part of the risk analysis process risk assessments are:

- Completed using a consistent risk assessment template to ensure that the full range of issues recognised in international standards are addressed.
- Drafted by an independent expert on the species and peer reviewed by a different expert.
- Approved by an independent risk analysis panel (known as the Non-native Species Risk Analysis Panel or NNRAP) only when they are satisfied the assessment is fit-for-purpose.
- Approved for publication by the GB Programme Board for Non-native Species.
- Placed on the GB Non-native Species Secretariat (NNSS) website for a three month period of public comment.
- Finalised by the risk assessor to the satisfaction of the NNRAP.

To find out more about the risk analysis mechanism go to: www.nonnativespecies.org

Common misconceptions about risk assessments

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted:

- Risk assessments consider only the risks posed by a species. They do not consider the practicalities, impacts or other issues relating to the management of the species. They therefore cannot on their own be used to determine what, if any, management response should be undertaken.
- Risk assessments are about negative impacts and are not meant to consider positive impacts that may also occur. The positive impacts would be considered as part of an overall policy decision.
- Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based.
- Completed risk assessments are not final and absolute. Substantive new scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.

Period for comment

Draft risk assessments are available for a period of three months from the date of posting on the NNSS website*. During this time stakeholders are invited to comment on the scientific evidence which underpins the assessments or provide information on other relevant evidence or research that may be available. Relevant comments are collated by the NNSS and sent to the risk assessor. The assessor reviews the comments and, if necessary, amends the risk assessment. The final risk assessment is then checked and approved by the NNRAP.

*risk assessments are posted online at:
https://secure.fera.defra.gov.uk/nonnativespecies/index.cfm?sectionid=51
comments should be emailed to nnss@fera.gsi.gov.uk

GB NON-NATIVE ORGANISM RISK ASSESSMENT SCHEME

For more information visit: www.nonnativespecies.org

Name of Organism:			***Procambarus* sp. - Marbled Crayfish**
Objectives:			Assess the risks associated with this species.
Version:			Original draft 23/02/11
Author:			D. Holdich
Suggested citation:			Holdich (2011). GB Non-native Organism Risk Assessment for *Procambarus* sp. www.nonnativespecies.org
Q NO.	**QUESTION**	**RESPONSE**	**COMMENT**

1	What is the reason for performing the Risk Assessment?	4	All non-indigenous crayfish species so far introduced into Britain have become established in the wild, i.e. *Astacus astacus*, *Astacus leptodactylus*, *Pacifastacus leniusculus*, *Procambarus clarkii*, *Orconectes limosus* and *Orconectes virilis*, and a seventh, *Cherax quadricarinatus*, is legally available through the aquarium trade and has on occasions has been found in the wild (Holdich et al., 2004; Holdich & Sibley, 2009). It is possible that if the marbled crayfish were released into British waters it could also become established and be a threat to the indigenous crayfish species, *Austropotamobius pallipes*. Due to its parthenogenetic life style it would only need a single individual marbled crayfish to initiate a population. *Procambarus* sp. has been imported into southern England via the ornamental fish trade on a number of occasions (Scott 2005, 2007, 2008, pers. comms), and it seems only a matter of time before this invasive species is found in the wild. A hobbyist in Southampton offloaded some at a pet shop because they were multiplying too fast – she threatened to dump them in a river if they did not take them (Scott 2005, pers. comm.). It appears easy to obtain small numbers of marbled crayfish advertised on the internet through the post to Britain from countries such as Germany. Scientific research indicates that this species can be invasive (Jones et al., 2009), produces large numbers of individuals in a few months (Vogt, 2008), and act as a vector of crayfish plague (Environment News, 2008). Non-indigenous crayfish (NICS) are being imported as tropical ornamentals from non-EU countries (mainly in SE Asia) and Border Inspection Posts have the authority to seize and destroy these, so the main problem is material being imported from the EU over which Border Inspection Posts have no control (Scott 2005, pers. comm.). Warnings have been given in Practical Fish Keeping (2007) about the illegality of keeping this species in Britain. Recently it has been suggested that the marbled crayfish is an ideal laboratory animal for research into development, epigenetics and evolutionary biology (Vogt, 2008; Jimenez & Faulkes, 2010b; Vogt, 2010). This could lead to it becoming popular in British research centres. Vogt (2008) states that the marbled crayfish can breathe out of water and can climb vertical glass walls so that great care should be taken if keeping it. One American internet site (Marbled Crayfish, 2009) gives a list of medical organizations interested in using marbled crayfish, although it makes the point that it will not supply them to the UK.
2	What is the Risk Assessment area?	England, Scotland and Wales	Not yet established in British waters. Ireland is not dealt with in this document as it has no non-indigenous crayfish species and strict controls to prevent their entry. However, the potential exists for illegal introductions into Ireland via the aquarium trade or through the post (marmorkrebs and other NICS are easy to obtain via the internet). Indeed, an unknown species of the Australian genus *Cherax* was discovered in a pet shop in the Irish Republic and was subsequently destroyed (J.D. Reynolds, 2007, pers. comm., 2007).

3	Does a relevant earlier Risk Assessment exist?	Since I submitted the original RA there have been two relevant studies although neither relates directly to Britain.	Tricarico et al. (2010) have used a screening tool for identifying potentially invasive freshwater invertebrates. The authors used a version of FI-ISK developed by Cefas (www.cefas.co.uk/4200.aspx), but which had not previously been used for crayfish. The scoring system consists of both qualitative and quantitative elements that assess the biogeography and history of the species, the presence of 'undesirable traits' and species biology and ecology, the premise being that species invasive in some parts of the world have an increased chance of being invasive in other areas with similar environments. This hazard identification tool kit was used to screen 37 crayfish species that were potentially invasive in Italy, including marmorkrebs, *Procambarus* sp. *Procambarus clarkii* and *Pacifastacus leniusculus* were found to be the species with most invasive potential, followed by *Orconectes limosus* and *Cherax destructor*, which were all considered 'high risk' species. *Procambarus* sp. was considered to be a 'medium risk' species, although no adverse impacts have been reported in Europe, and only a single specimen has been found in Italy. Chucholl (2010a) has assessed the risk of invasive crayfish being available through the aquarium trade with particular emphasis on the situation in Germany. Germany is the main importer of NICS into Europe. In total, 123 NICS have been available as ornamental aquarium species, of which 107 originate from North or Central America, and so could be suspected of carrying crayfish plague. In 2009, at least 37 species were offered by on-line shops. FI-ISK, availability, likelihood of intentional release (because they became a nuisance in aquaria), and price were used to predict their invasive state. Important unfavoured traits are unrestricted or unwanted reproduction, and reproducing more than once a year, such as in parthenogenetic species. This can occur in cambarid species with an *annulus ventralis*, where sperm can be stored for several months. On a 'nuisance' index, Chucholl rated *Procambarus* sp., *P. clarkii* and *Cherax quadricarinatus* the highest amongst crayfish sold as ornamentals. It should be noted that a wild, breeding population of *C. quadricarinatus* has been found in a river heated by springs in Slovenia (Jaklič & Vrezec, 2010). This species is widely available in the aquarium trade in Britain and individuals have occasionally been dumped in the wild (S. Peay, 2009, pers. comm.). It is possible that it could become established where heated effluents enter rivers (as was pointed out by me when Cefas allowed this species to be the only species that the aquarium trade could import from outside Europe). It could become established here if dumped into a warm water site, e.g. where heated effluents occur.
4	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?	No	No

A	**Stage 2: Organism Risk Assessment** **SECTION A: Organism Screening**		
5	Identify the Organism. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Yes – but there is still some confusion over its idemtity	The taxonomic identity of this species is uncertain. Molecular genetic studies have shown it to be a member of the North American crayfish family Cambaridae, and to belong to the genus *Procambarus*. That is certain. Initially, it was shown by molecular techniques that the nearest relative to this unknown species was *Procambarus* (*Ortmannicus*) *fallax* (Hagen, 1870) (Scholtz et al., 2002). However, subsequent studies indicated that it was close to *Procambarus* (*Leconticambarus*) *alleni* (Faxon, 1884) (Crandall 2005, *pers. comm.*). Sequencing of the cytochrome oxidase gene has shown that *Procambarus* sp. specimens from Austria, at least, were not the same as *Procambarus alleni* obtained from cultures in Austria, but were closer to *Procambarus* (*Pennides*) *spiculifer* (LaConte, 1856) (Fetzner 2006, pers. comm.). Subsequent comparison of *P. alleni* with *Procambarus* sp. indicated marked differences in the morphology of *Procambarus* sp. and *Procambarus alleni* (Pöckl 2006, pers. comm.). Recently, Martin et al. (2010b) have re-evaluated the status of marmorkrebs using morphological and molecular means. They are fairly certain that it is indeed the parthenogenetic form of *Procambarus fallax*, which is native to peninsular Florida and southern Georgia. It can usually be distinguished from other *Procambarus* spp. by its marbled appearance and the small size of its chelipeds, which are weakly granulate (Pöckl et al., 2006; Souty-Grosset et al., 2006). However, Martin et al. (2010b) found a single individual in Saxony which, although it was confirmed as marmorkrebs by molecular techniques, had rather different body patterns and a totally different rostrum shape.
6	If not a single taxonomic entity, can it be redefined?	N/A	

7	Is the organism in its present range known to be invasive, i.e. to threaten species, habitats or ecosystems?	Not known	*Procambarus* sp. has no native range as such as it is not known where it originated from. There is even a suggestion that it might be a genetically engineered species (Scholtz et al., 2002). A single specimen was recently found amongst a population of *Procambarus clarkii* in Italy (Marzano et al., 2009), probably having been dumped from an aquarium (Gherardi 2009, pers. comm.). In Germany only two localized records were known when this report was originally written (Marten et al., 2004; Schulz et al., 2009). In the Netherlands one population has been known since 2004 (Souty-Grosset et al., 2006), but apparently individuals are only present in small numbers and are difficult to catch (Koese 2009, pers. comm.). The situation has changed in 2010, for Germany at least. Martin et al. (2010a) have recorded an individual in Saxony and on the basis of this they question the actual threat to European freshwater ecosystems that marmorkrebs poses, because most records in Europe are based on individuals or only a few individuals. However, Ott (Ott 2010, pers. comm.) considers that marmorkrebs has a big potential to be a threat in Germany. It is easily available on-line and in shops. They are being passed between people. Some are being kept in garden ponds. Those with too many threaten to dump them in nearby waterways, and this has happened. More recently, Chucholl (Chucholl 2010b, pers. comm.) has found a well-established marmorkrebs population living with *Orconectes limosus* in the vicinity of the upper Rhine. One was found in the outflow, and so it may have already invaded the river Rhine. More than 50 individuals were found of several size classes, including three egg-bearing females, throughout the lake margin. The situation is very different in Madagascar where many wild populations have been found (Jones et al., 2009) and are spreading due to the actions of man (Kawai et al., 2010). Their origin is unknown, but *Procambarus* sp. was thought to have been introduced in 2003 and was noticed in fish markets by non-locals in 2007. Many populations were subsequently found in all types of waterbody (including rice fields). Individuals were found to breed a number of times a year and as many as 500 eggs were found on some. So far populations are mostly centred round the capital and it has not yet impinged on stocks of the indigenous *Astacoides* spp. Specimens tested were not found to be positive for crayfish plague. Currently it is not possible to say what the impact will be on the freshwater environment of Madagascar, but all the signs are that it will be spread to new areas by locals and probably also spread naturally.

8	Does the organism have intrinsic attributes that indicate that it could be invasive, i.e. threaten species, habitats or ecosystems?	YES	*Procambarus* sp. is unique amongst the decapod crustaceans in being parthenogenetic (Vogt 2008). It is capable of breeding a number of times a year, is highly fecund, and with rapid individual growth (Scholtz et al., 2002; Vogt et al., 2004; Vogt & Tolley, 2004; Seitz et al., 2005; Alwes & Scholtz, 2006). It is widely available on the internet and in aquarist centres in mainland Europe, where it is a popular pet due to its high degree of resistance to handling, its fast mode of reproduction and its attractive appearance. A Google search revealed 1500 hits for 'Marmorkrebs' in June 2009, many of which related to hobbyists (particularly German) exchanging information or trying to offload excess stock. All marbled crayfish examined so far by scientists have been female. However, it should be pointed out that, with the exception with what is happening in Madagascar, nearly all observations are based on aquarium cultures. After hatching from the eggs juveniles pass through a number of stages before reaching sexual maturity at a total length of *c.* 4 cm, sometimes less. The viability, defined as the number of stage 3 juveniles (first free living stage) divided by the pleopodal egg number, is often higher than 80%. The external sexual characters are first recognizable in stage 4 juveniles and are structurally complete around 2 months after hatching in specimens of *c.* 2 cm total length. At 25°C the first spawning occurs on average at an age of 25 weeks, at 20°C after 35 weeks. Under very good conditions marbled crayfish can reproduce all year round, with intervals of only 8-9 weeks between spawning. In general, the brood size increases with female size and can exceed 500 eggs, but most of the smaller specimens have egg numbers of 50-150. Maximum growth occurs at 25^{o}C, whereas maximum survival is at 20^{o}C. It can withstand temperatures <8^{o}C and >30^{o}C for many weeks. It can apparently survive winter conditions in ponds that freeze over (Pöckl et al., 2006). A close relative, *P. clarkii*, supposedly a sub-tropical species, has survived in ponds on Hampstead Heath and local canals since the 1980s (Holdich et al., 1995; Ellis & England, 2008). As females reproduce through unfertilized, haploid eggs (parthenogenesis), a single specimen can therefore start a population. Adults can reach a size of 13 cm TL but are more often <10 cm. It will eat almost anything under culture conditions. It has been shown to be capable of carrying crayfish plague (Environmental News Service, 2008).
9	Does the organism occur outside effective containment in the Risk Assessment area?	NO	No records to date.

10	Is the organism widely distributed in the Risk Assessment area?	NO	It has only been detected in Britain through the aquarium trade and from individuals brought into pet shops, presumably by people who have bought them on the internet or obtained them from aquarist centres, where it is illegal to stock them. However, Scott and Stebbing (Scott 2010, pers. comm.; Stebbing 2010, pers. comm.) have informed me that Cefas has not come across them in recent years .Third country imports are always screened at Border inspection posts and *Procambarus* sp. has not been seen in such consignments. Cefas have stopped the trade in marmorkrebs on eBay. They are authorizing all fish importers, so this should get the message over to some of the people who source ornamentals in Europe, to stop them bringing back any NICS.
11	Does at least one species (for herbivores, predators and parasites) or suitable habitat vital for the survival, development and multiplication of the organism occur in the Risk Assessment area, in the open, in protected conditions or both?	YES	Indications from laboratory experiments show that *Procambarus* sp. is tolerant of a wide range of environmental conditions (Pöckl 2009, pers. comm.). However, it is not known if it could survive in the wild in Britain, although it does in Germany and the Netherlands, where similar conditions prevail. *Procambarus fallax*, the slough crayfish, which may well be marmorkrebs, inhabits wetlands of peninsular Florida and southern Georgia in the USA, where the minimum winter temperature falls to 6^{o}C in the north of its range. It is generally more abundant in permanent water bodies or temporary wetlands. It is a tertiary burrowing species, only burrowing under extreme conditions. Similar climatic conditions apparently occur in Madagascar. Martin et al. (2010b) wonder whether marmorkrebs could persist in northern and central European lakes or streams where temperatures drop to 4^{o}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 et al. (2005) show that it has substantial cold tolerance, although its temperature optimum is high at 18-25^{o}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 2010b, pers. comm.).
12	Does the organism require another species for critical stages in its life cycle such as growth (e.g. root symbionts), reproduction (e.g. pollinators; egg incubators), spread (e.g. seed dispersers) and transmission, (e.g. vectors)?	NO	N/A

13	Is the other critical species identified in question 12 (or a similar species that may provide a similar function) present in the Risk Assessment area or likely to be introduced? If in doubt, then a separate assessment of the probability of introduction of this species may be needed.	N/A	N/A
14	Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment area or sufficiently similar for the organism to survive and thrive?	YES	Populations have survived for a number of years in Germany and the Netherlands where the ecoclimatic zones are very similar to those in Britain. However, it has become most prevalent on the tropical island of Madagascar. See comments under 11 above.
15	Could the organism establish under protected conditions (e.g. glasshouses, aquaculture facilities, terraria, zoological gardens) in the Risk Assessment area?	YES	*Procambarus* sp. does extremely well under protected conditions such as in aquaria, and most of the observations in the published literature are based on those made on individuals in culture conditions.
16	Has the organism entered and established viable (reproducing) populations in new areas outside its original range, either as a direct or indirect result of man's activities?	YES	*Procambarus* sp. does not have an original range. It was first discovered in aquaria in Germany (Scholtz et al., 2003; Vogt, 2008). However, if marmorkrebs is the slough crayfish, *Procambarus fallax* (Martin et al., 2010b), then this species inhabits wetlands of peninsular Florida and southern Georgia in the USA. It then became widely available throughout the aquarist trade in the Northern Hemisphere and this has been a direct result of man's activities.
17	Can the organism spread rapidly by natural means or by human assistance?	YES	There is evidence for human assistance in Madagascar where locals are moving it around the island and seeding water bodies with it (Jones et al., 2009; Kawai, 2010). In Germany, the Netherlands and Italy occurrences of *Procambarus* sp. in the wild are probably due to hobbyists dumping them.
18	Could the organism as such, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment area?	YES	Firstly, it has been shown to be a vector of crayfish plague by a British worker (Environment News Service, 2008) and therefore it could pose a further threat to the already endangered indigenous crayfish species, *Austropotamobius pallipes*. Secondly, if it became established in British waters then it could produce large numbers of individuals, which would impinge on the aquatic environment, in much the same way that the signal crayfish, *Pacifastacus leniusculus*, has (Peay et al., 2009).

19	This organism could present a risk to the Risk Assessment area and a detailed risk assessment is appropriate.	Detailed Risk Assessment Appropriate	The potential for *Procambarus* sp. to enter the British freshwater environment water is high.
20	This organism is not likely to be a harmful non-native organism in the Risk Assessment area and the assessment can stop.	N/A	N/A

B	SECTION B: Detailed assessment of an organism's probability of entry, establishment and spread and the magnitude of the economic, environmental and social consequences			
	Probability of Entry	**RESPONSE**	**UNCERTAINTY**	**COMMENT**
1.1	List the pathways that the organism could be carried on. How many relevant pathways can the organism be carried on? (See Notes section)	Few	LOW	Via the aquarium trade in ornamentals: either via the internet or via individuals purchasing them in mainland Europe and bringing them into Britain.
1.2	Choose one pathway from the list of pathways selected in 1.1 to begin the pathway assessments.			Aquarium trade. Hobbyists are offering excess stock for sale on the internet. One enquiry (27-06-09) by a colleague to a German hobbyist advertising marbled crayfish for sale was told he could have the only one he had left for 10 euros, posted to Britain in a small parcel (Brickland 2009, pers. comm.).
1.3	How likely is the organism to be associated with the pathway at origin?	Very unlikely	LOW	There are many internet sites offering *Procambarus* sp. for sale and it can be legally imported into Britain from EU-countries. However, their sale and keeping is regulated once they are in Britain (Scott, 2000). It is illegal to import them into Britain from a non-EU country as only the tropical Australian crayfish, *Cherax quadricarinatus*, is allowed to be imported. A single individual amongst a consignment of ornamental fish, for example from SE Asia, may not be spotted at BIPs. However, as mentioned above (Scott 2010, pers. comm.; Stebbing 2010, pers. comm..) Cefas has not come across any being imported by traditional routes in recent years.
1.4	Is the concentration of the organism on the pathway at origin likely to be high?	Unlikely	LOW	A single parthenogenetic female would be enough to start a population, e.g. advice was sought by a customer in an aquarium shop as a single specimen she had obtained had produced around 100 individuals in 8 months (Scott 2005, *pers. comm*.).
1.5	How likely is the organism to survive existing cultivation or commercial practices?	Very likely	LOW	*Procambarus* sp. breeds very well under aquarium condition.
1.6	How likely is the organism to survive or remain undetected by existing measures?	Likely	LOW	If a large number of individuals were present in a consignment of ornamental fish then it is likely they would be detected at BIPs, but if it were a single female then it is less likely.
1.7	How likely is the organism to survive during transport /storage?	Very likely	LOW	This would depend on the time taken and the amount of water available. Vogt (2008) states that the marbled crayfish can breathe in air and can be housed without aeration as long as they have access to surface water. *Procambarus* sp. appears to be a very tolerant crayfish and obviously survives being posted to internet customers.
1.8	How likely is the organism to multiply/increase in prevalence	Likely	MEDIUM	Evidence is lacking, but in theory this is likely if a female with attached eggs was transported and these hatched during transport.

	during transport /storage?			
1.9	What is the volume of movement along the pathway?	Minimal	MEDIUM	It is probably minimal into Britain, but not in mainland Europe, USA (the marbled crayfish can be kept legally in at least 13 US states and one Canadian province; the earliest report dating back to 2005 (Jimenez & Faulkes, 2009)) and SE Asia. Many internet aquarist sites advertise *Procambarus* sp. for sale, hobbyists advertise excess stock for sale, and scientific publications are extolling its virtues for research purposes (e.g. Vogt, 2008). Faulkes (2009) has written a blog entitled "How Marmorkrebs can make the world a better place." He has also set up a weekly updated web site as a source of information for the *Procambarus* sp. research community (http://marmorkrebs.org/). An aquarist magazine in the USA is actively promoting marmorkrebs for pets and aquaculture (Robbins, 2009).
1.10	How frequent is movement along the pathway?	Occasionally	MEDIUM	According to Scott (Scott 2008, 2010, pers. comm.) Cefas have taken control of a number of consignments of marbled crayfish that have turned up in British aquarist centres, but none have been recorded in recent years.
1.11	How widely could the organism be distributed throughout the Risk Assessment area?	Widely	MEDIUM	With the ease by which live specimens can be obtained via the internet there could be many people throughout Britain who are keeping marbled crayfish as pets. If they get an excess of stock then they may dump them into the environment if they cannot offload them onto somebody else.
1.12	How likely is the organism to arrive during the months of the year most appropriate for establishment?	Likely	MEDIUM	The marbled crayfish could be imported at any time of the year but it is more likely to be come established in the warmer summer months as it grows better at temperatures over 20^{o}C (see above).
1.13	How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) or other material with which the organism is associated to aid transfer to a suitable habitat?	N/A	LOW	N/A
1.14	How likely is the organism to be able to transfer from the pathway to a suitable habitat?	Likely	MEDIUM	This could only occur if individuals were disposed of into the freshwater environment or if they escaped from holding tanks. Vogt (2008) states that they can climb glass walls.

	Probability of Establishment			
1.15	How similar are the climatic conditions that would affect establishment in the Risk Assessment area and in the area of current distribution?	Similar and Not similar	LOW	In mainland Europe *Procambarus* sp. has been recorded from ponds and lakes in Germany, Italy and the Netherlands. In Germany and the Netherlands climatic conditions are very similar to those in Britain. However, *Procambarus* sp. cannot be considered as invasive in those countries yet. This has only happened on the tropical island of Madagascar where climatic conditions are very different from those in Europe. It may be that *Procambarus* sp. is a sub-tropical species and that it will not fare as well in temperate conditions – see below, however. If marmorkrebs is the slough crayfish, *Procambarus fallax* (Martin et al., 2010b), then this species inhabits wetlands of peninsular Florida and southern Georgia in the USA, where the minimum winter temperature falls to 6^{o}C in the north of its range. It is generally more abundant in permanent water bodies or temporary wetlands. It is a tertiary burrowing species, only burrowing under extreme condition. Similar climatic conditions apparently occur in Madagascar. Martin et al. (2010b) wonder whether marmorkrebs could persist in northern and central European lakes or streams where temperatures drop to 4^{o}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 et al. (2005) show that it has substantial cold tolerance, although its temperature optimum is high at 18-25^{o}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).
1.16	How similar are other abiotic factors that would affect establishment in the Risk Assessment area and in the area of present distribution?	Similar and Not similar	LOW	The same answer applies as to 1.15
1.17	How many species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism species are present in the Risk Assessment area? Specify the species or habitats and indicate the number.	Very many	LOW	Very many suitable habitats are present in Britain. *Procambarus* sp. does not appear to have been found in running water where it occurs yet, but, if climatic and abiotic conditions were suitable then it could occupy 1000s of hectares of still waters in Britain. Vogt (2008) mentions that *Procambarus alleni* and *Procambarus fallax*, which are supposedly very similar to *Procambarus* sp. (although gonochoristic), coexist in some subtropical sloughs of South Florida. *P. alleni* is ubiquitous to wetlands in South Florida and endemic to

				Florida. It is found in a variety of fresh and brackish water habitats ranging from short-hydroperiod waters to perennially flooded sloughs. It prefers densely vegetated habitats and excavates temporary burrows to survive the dry season (Dorn & Trexler, 2007). Vogt (2008) suggests that these biological characteristics may well explain the eurytopicity of the marbled crayfish. *Procambarus clarkii* also possesses similar characteristics (Gherardi, 2007), but in Britain it has become acclimated to living in conditions of permanent water, which may well freeze over in winter.
1.18	How widespread are the species (for herbivores, predators and parasites) or suitable habitats vital for the survival, development and multiplication of the organism in the Risk Assessment area?	Widespread	LOW	Very many suitable habitats are present throughout Britain. *Procambarus* sp. has apparently not yet been found in running water, but, if climatic and abiotic conditions were suitable then it could occupy 1000s of hectares of still waters in Britain. It is most likely to become established in southern and eastern lowland England, including wetlands that do not have crayfish present. Marmorkrebs is less likely to become established in cooler northern and western regions, although this may change with climate change. See comments under A. 11 about *P. fallax*.
1.19	If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in the risk assessment area?	N/A	LOW	N/A
1.20	How likely is it that establishment will not be prevented by competition from existing species in the Risk Assessment area?	Moderately likely	MEDIUM	Indications are that in an aquarium at least the marbled crayfish is not so aggressive as other crayfish species (Pöckl et al., 2006; Souty-Grosset et al., 2006). This may in part be due to the small size of its claws. All crayfish currently in Britain have much larger claws and so might dominate in any mixed populations (Holdich & Sibley, 2009). However, Jiminez & Faulkes (2010a) found that marmorkrebs could compete effectively against *Procambarus clarkii* in paired fights, and Chucholl (Chucholl 2010b, pers. comm.) has recently found it living together with *Orconectes limosus* in a lake in Germany.
1.21	How likely is it that establishment will not be prevented by natural enemies already present in the Risk Assessment area?	Moderately likely	MEDIUM	Fish, birds and other invertebrates would be likely to feed on the marbled crayfish. However, the sheer numbers it is capable of producing may lessen any impact of predation.
1.22	If there are differences in man's management of the environment/habitat in the Risk Assessment area from that in the	Unlikely	LOW	Legislation is more stringent for non-indigenous species in Britain than in most other countries, but it is difficult to enforce (Holdich & Pöckl, 2005). So, legislation is not likely to aid establishment. Nothing is known about the management of the environment/habitat in the

	area of present distribution, are they likely to aid establishment? (specify)			Netherlands and Germany where the marbled crayfish occurs, but nothing has yet been done to try and eradicate the species.
1.23	How likely is it that existing control or husbandry measures will fail to prevent establishment of the organism?	Very likely	Medium	There appears to be no easy way to control non-indigenous crayfish without employing a great deal of manpower and spending a great deal of money. At the end of the day it will probably be a combination of mechanical, chemical, physical and biological methods that will have to be employed (Holdich et al. 1999, Stebbing et al., 2003a, b; Ribbens and Graham 2004; Peay et al., 2006; Aquiloni et al 2009). No populations of the related species *P. clarkii* have been eradicated to date.
1.24	How often has the organism been recorded in protected conditions, e.g. glasshouses, elsewhere?	Widespread	LOW	Indications are from contacts all over Europe that *Procambarus* sp. is widely available through the aquarium trade. It does extremely well in the protected conditions of an aquarium.
1.25	How likely is the reproductive strategy of the organism and duration of its life cycle to aid establishment?	Very likely	LOW	Uniquely amongst crayfish *Procambarus* sp. is parthenogenetic. After hatching from the eggs juveniles pass through a number of stages before reaching sexual maturity at a total length of *c.* 4 cm, sometimes less. The viability, defined as the number of stage 3 juveniles (first free living stage) divided by the pleopodal egg number, is often higher than 80%. The external sexual characters are first recognizable in stage 4 juveniles and are structurally complete around 2 months after hatching in specimens of *c.* 2 cm total length. At 25°C the first spawning occurs on average at an age of 25 weeks, at 20°C after 35 weeks. Under very good conditions marbled crayfish can reproduce all year round, with intervals of only 8-9 weeks between spawning. In general, the brood size increases with female size and can exceed 500 eggs, but most of the smaller specimens have egg numbers of 50-150. As females reproduce through unfertilized, haploid eggs (parthenogenesis), a single specimen can therefore start a population. Adults can reach a size of 13 cm TL but are more often <10 cm.
1.26	How likely is it that the organism's capacity to spread will aid establishment?	Moderately likely	MEDIUM	There is no information on the ability of the marbled crayfish to spread naturally as all occurrences seem to have been human-mediated. However, as with other non-indigenous crayfish species in Britain, there is no reason to believe that if it became established it could not spread naturally. Vogt (2008) has mentioned that it can survive out of water and climb glass walls and aeration pipes.
1.27	How adaptable is the organism?	Adaptable	MEDIUM	In Madagascar it appears to have adapted to a wide range of habitats (Jones et al., 2009). In the Netherlands it lives in a lake and in

				Germany in ponds. Vogt (2008) says that it is eurytopic and can breathe out of water. He also mentions that a close relative can survive in brackish water. There are reports that it can survive winter conditions in ponds that freeze over (Pöckl et al., 2006). Under aquarium conditions it appears able to survive a wide range of temperatures.
1.28	How likely is it that low genetic diversity in the founder population of the organism will not prevent establishment?	Unlikely	MEDIUM	This has certainly not been the case in Madagascar, where presumably only a small number of individuals were originally imported (Jones et al., 2009). In fact Marzano et al. (2009) mention that there is an unusually high degree of genetic polymorphism for a parthenogenetic species such as *Procambarus* sp., which is deposited in the Genbank.
1.29	How often has the organism entered and established in new areas outside its original range as a result of man's activities?	Few	LOW	The original range of *Procambarus* sp. is unknown – it was discovered in an aquarium display in Germany (Vogt, 2008). It is now well established amongst hobbyists throughout mainland Europe, the USA and SE Asia. It has only been recorded from five countries in the wild, i.e. Germany, the Netherlands, Italy, Madagascar and Japan, and in each case this has been due to man's activities.
1.30	How likely is it that the organism could survive eradication campaigns in the Risk Assessment area?	Likely	MEDIUM	There appears to be no easy way to control non-indigenous crayfish without employing a great deal of manpower and spending a great deal of money. At the end of the day it will probably be a combination of mechanical, chemical, physical and biological methods that will have to be employed. There is only a short time period in which control of any recently established crayfish population can be eradicated and all potential methods have impacts on non-target organisms.
1.31	Even if permanent establishment of the organism is unlikely, how likely is it that transient populations will be maintained in the Risk Assessment area through natural migration or entry through man's activities (including intentional release into the outdoor environment)?	Likely	MEDIUM	It is possible that transient populations will be maintained through man's activities, i.e. hobbyists dumping unwanted stock.

	SPREAD	RESPONSE	UNCERTAINTY	COMMENT
2.1	How rapidly is the organism liable to spread in the Risk Assessment area by natural means?	Intermediate	MEDIUM	There are no records of *Procambarus* sp. spreading naturally, except in Madagascar. However, based on experiences with other NICS in Britain this would be a possibility through natural migration in rivers and streams and as a result of floods.
2.2	How rapidly is the organism liable to spread in the Risk Assessment area by human assistance?	Intermediate	MEDIUM	Populations may develop as a result of *Procambarus* sp. (one individual may be enough) being dumped by hobbyists, but the actual spread is more likely to involve anglers who may move them from one water body to another as a supplemental food for fish or as bait as has been done with other NICS (Holdich & Black, 2008; Peay & Hiley, 2004; Peay et al., 2009).
2.3	How difficult would it be to contain the organism within the Risk Assessment area?	Very difficult	LOW	Once a non-indigenous crayfish becomes established it is very difficult to contain or remove. However, if the crayfish were discovered early on and the population was contained in a pond or small lake then appropriate eradication measures (see above) could be employed.
2.4	Based on the answers to questions on the potential for establishment and spread define the area endangered by the organism.	Widespread in Britain	MEDIUM	Suitable lacustrine habitats in England, Scotland and Wales.

	IMPACTS	RESPONSE	UNCERTAINTY	COMMENT
2.5	How important is economic loss caused by the organism within its existing geographic range?	Moderate	MEDIUM	*Procambarus* sp. does not have an existing range. The only region that it is prevalent in is Madagascar. There are worries there that it might impact on the rice crop but there is no evidence that this is happening yet (Jones et al., 2009).
2.6	Considering the ecological conditions in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, livestock health and production, likely to be? (describe) in the Risk Assessment area, how serious is the direct negative economic effect of the organism, e.g. on crop yield and/or quality, likely to be?	Minor	MEDIUM	*Procambarus* sp. has not become established to any great extent in mainland European countries that have a similar climate to Britain so no information is available from that source. If *Procambarus* sp. became established in the Britain it would be likely to impact on the trophic structure of freshwater bodies as other non-indigenous crayfish have. This would be due to its large numbers and high intensity of feeding. It is not known if it burrows. If it came in contact with the indigenous crayfish species then it could possibly transmit crayfish plague to it. It may impact on recreational fisheries in much the same way that the signal crayfish has (Peay & Hiley, 2004). However, the presence of a new food source in the aquatic environment would be of benefit to predators, in particular fish and birds.
2.7	How great a loss in producer profits is the organism likely to cause due to changes in production costs, yields, etc., in the Risk Assessment area?	Minor	MEDIUM	*Procambarus* sp. may have an adverse impact on recreational angling and consequently fees charged for fishing, but presence of a new food source in the aquatic environment would be of benefit to predators, in particular fish and birds. It might have a minor impact on producer profits gained from signal crayfish if it were to dominate (an unlikely scenario) as the meat yield would be likely to be less due to the small size of the claws and the smaller maximum sized reached.
2.8	How great a reduction in consumer demand is the organism likely to cause in the Risk Assessment area?	Minimal	MEDIUM	If *Procambarus* sp. were to dominate in crayfish waters then it is likely that demand would switch to it although there is likely to be less meat in this crayfish than in signals.
2.9	How likely is the presence of the organism in the Risk Assessment area to cause losses in export markets?	Moderately likely	MEDIUM	If *Procambarus* sp. were to become dominant in crayfish waters then this would impact on the small export trade in signal crayfish, and also possibly on that of *Astacus leptodactylus*. In the latter case this likely be due to the impact of crayfish plague on this species.
2.10	How important would other economic costs resulting from introduction be? (specify)	Minimal	HIGH	If *Procambarus* sp. proves to be a burrower like the signal crayfish then it could impact on bank structure and consequently flood defences.
2.11	How important is environmental harm caused by the organism within its existing geographic	Minimal	LOW	None has been reported from mainland Europe. Studies are in progress in Madagascar to ascertain whether it is damaging the rice crop.

	range?			
2.12	How important is environmental harm likely to be in the Risk Assessment area?	Moderate	MEDIUM	If *Procambarus* sp. become established in Britain it may well have a negative impact on the freshwater environment due to its large numbers and high feeding activity. It may spread crayfish plague into populations of the indigenous crayfish. It may impact on recreational angling in the same manner as signal crayfish.
2.13	How important is social and other harm caused by the organism within its existing geographic range?	Minimal	LOW	*Procambarus* 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, 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 et al., 2009).
2.14	How important is the social harm likely to be in the Risk Assessment area?	Minor	MEDIUM	If *Procambarus* sp. were to become established in the Britain its main social impact would be on recreational anglers, and from a conservation point of view on the indigenous crayfish, *Austropotamobius pallipes*.
2.15	How likely is it that genetic traits can be carried to native species, modifying their genetic nature and making their economic, environmental or social effects more serious?	Very unlikely	LOW	The indigenous crayfish belongs to the family Astacidae whilst *Procambarus* sp. belongs to the Cambaridae. The two families have different mating systems and could not interbreed.
2.16	How probable is it that natural enemies, already present in the Risk Assessment area, will have no affect on populations of the organism if introduced?	Very likely	LOW	Predators such as fish, birds and some aquatic invertebrates will have some impact on crayfish numbers but probably not enough to control an expanding population of this parthenogenetic crayfish.
2.17	How easily can the organism be controlled?	Very difficult	LOW	As far as I am aware nobody has tried to control it yet, but experience with other non-indigenous crayfish in Britain suggests that it would be very difficult to control once established. See Section 1.23
2.18	How likely are control measures to disrupt existing biological or integrated systems for control of other organisms?	Unlikely	MEDIUM	If a draindown, or infill, or use of biocides were implemented then this would be of likely benefit to the control of other damaging organisms.
2.19	How likely is the organism to act as food, a host, a symbiont or a vector for other damaging organisms?	Very likely	LOW	An expanding population of *Procambarus* sp. would be of benefit to non-indigenous predators as a food source, especially for fish. *Procambarus* sp. has been shown to be a vector for crayfish plague and thus would become a danger to the indigenous crayfish, *Austropotamobius pallipes*, as have other North American species in Britain.

2.20	Highlight those parts of the endangered area where economic, environmental and social impacts are most likely to occur	Very likely	MEDIUM	In areas where the indigenous crayfish occurs – mainly central and northern parts of England and Wales. Any body of water used for angling as has happened with the signal crayfish, *Pacifastacus leniusculus* (Peay & Hiley, 2004).

	Summarise Entry	Very likely	LOW	*Procambarus* sp. is unique amongst crayfish in that its taxonomy and geographical origin are unresolved and in being parthenogenetic. This latter feature gives it a great advantage when colonizing new waters. It is fast growing, highly fecund and has the capacity under the right conditions to breed all year round. It can produce large numbers in a relatively short space of time. It is very popular as a pet in mainland Europe due to its attractive appearance and ease of handling. Currently it is only prolific in Madgascar where it has been introduced from an unknown source. It is a new source of food and revenue for local people but may also impact on crops such as rice (Jones et al., 2009). Its speed of breeding and growth has led to a problem for hobbyists as they quickly end up with superfluous stock. Some of this is on sale via the internet. Some is given or sold back to aquarist centres. Some, however, is dumped in the freshwater environment. This activity has given rise to localized populations in Germany and the Netherlands. A single individual has also been found in the wild in Italy. It has not yet been recorded from the wild in Britain, although it has cropped up in some aquarist centres and is being kept by members of public. This activity is illegal in both cases. The biological features of *Procambarus* sp., particularly its parthenogenicity, have lead to it being heralded as the new fruit fly for studies into development, epigenetics and evolutionary biology (Vogt, 2008, 2010; Jimenez & Faulkes, 2010b). This is likely to lead to it becoming a popular research tool in research establishments. It is probably only a matter of time before we have another NICS in British waters.
	Summarise Establishment	Likely	LOW	It seems highly probable that *Procambarus* sp. will be released into the wild in Britain before long, if this has not already happened. If it becomes a popular research tool and its keeping is licensed in Britain then there is good chance of specimens escaping, some of which may reach local water courses. Whether or not it could become established is unknown, but suffice to say that all NICS so far introduced into Britain, with the exception of *Cherax quadricarinatus*, have become established in the wild (Holdich & Sibley, 2009). However, *Procambarus* sp. has so far only done really well under the tropical

				conditions of Madagascar (Jones et al., 2009) and it may not do so well under temperate conditions. However, the recent finding of a thriving population in a lake in the upper Rhine area of Germany (Chucholl 2010b, pers. comm.) alters this perception and makes establishment in Britain more likely.
	Summarise Spread	Slow	MEDIUM	Populations of marmorkrebs in the Netherlands and Italy have not yet spread naturally beyond their introduction sites. However, in Germany Chucholl (Chucholl 2010b, pers. comm.) has recorded one individual in the outflow from a lake containing a lake population, and so may have already invaded the river Rhine. The majority of populations of non-indigenous crayfish in Britain are the result of man's activities. As seen from the introduction of the signal crayfish *Pacifastacus leniusculus* into Britain in the late 1970s, colonization can be relatively rapid, i.e. it took less than 25 years for this non-indigenous species to occupy more 10 km squares than the indigenous *Austropotamobius pallipes* (Sibley 2003, Holdich et al. 2004). The spread of *Procambarus* sp. is unlikely to be this rapid as it would be unlikely to have such a commercial value as a luxury food as *P. leniusculus* has.
	Summarise Impacts	Moderate	MEDIUM	At the present time no adverse impacts have been attributed to *Procambarus* sp. in those countries where it has become established. The genus *Procambarus* has very many species, but only *P. clarkii*, the red swamp crayfish, has had a negative impact on the environment where it has been introduced, particularly in France, Italy and Spain (Souty-Grosset et al., 2006; Gherardi, 2007). It can change the trophic structure of a water body (Rodriguez et al., 2005) and cause damage by burrowing, as well as acting as a vector of crayfish plague (Souty-Grosset et al., 2006). *Procambarus clarkii* has many of the biological characteristics of *Procambarus* sp.; however, it is not parthenogenetic. In Britain it is only known from ponds and canals in London. If *Procambarus* sp. were to become established and widespread it may have some impact on recreational angling, although due to its smaller size this might be negligible. If it were to replace the signal crayfish then this may have some impact on any commercial enterprises harvesting signal crayfish from the wild to sell for the table at home or abroad. According to Peay (Peay 2010, pers. comm.) there is a lag phase

				before NICS start to spread significantly, e.g. *Procambarus clarkii*, a species closely related to marmorkrebs, has been known from sites in north London since the 1980s, but has only recently started to expand its range. So, even if marmorkrebs has established itself in Britain it may be a few years before it is noticed. It is likely that the population found by Chucholl (see above) in Germany has been present for a number of years and has been feeding individuals into the river Rhine, but has only just been discovered.
	For pathway/policy risk assessment Assess the potential for establishment and economic/environmental/social impacts of another organism or stop	N/A	N/A	N/A
	Conclusion of the risk assessment	MEDIUM	MEDIUM	Given the popularity of *Procambarus* sp. amongst hobbyists, the ease with which it can be obtained, and recommendations for its use as a laboratory animal, it seems likely that it will become established in British waters before long, either due to deliberate introductions or escapes. It is eurytropic and may well be able to adapt to the British climate as have all the other non-indigenous crayfish species introduced into Britain.
	Conclusions on Uncertainty	MEDIUM	LOW	Very little is known about the biology of *Procambarus* sp. outside of the laboratory and what has been recorded from the tropical island of Madagascar, so some of what I have written is speculation. The populations in Germany and the Netherlands have not been studied in any detail, but at least one in Germany seems to be thriving and living with *Orconectes limosus*. It has also been shown to be capable of holding it own in fights with another crayfish species. All indications are that marmorkrebs could survive, at least in areas of lowland Britain with an equable climate. Due to its environmental tolerances and high fecundity it is likely to outcompete the white-clawed crayfish, even if it were not carrying crayfish plague, should they come into contact.

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